

Express Mailing# EV221422999US

FREEZE PROTECTION FOR HEAT PUMP SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to heat pump systems and more particularly to a method and system for protecting against freezing in a liquid-heating heat pump system.

[0002] In vapor compression heat pump systems, heat is extracted from a typically low temperature source, pumped to higher pressure and temperature, and delivered to a typically higher temperature sink. In liquid-heating systems (usually water-heating systems), the fluid that is heated is commonly stored in a reservoir with a cold section and a hot section. The liquid is normally drawn from the cold section of the storage reservoir by a pump, heated in the heat pump in a heat exchanger by exchanging heat with the working fluid of the heat pump system and then deposited in the hot section of the storage reservoir.

[0003] The efficiency of the heat pump system is commonly a function of the temperature of the liquid to be heated where the colder the liquid to be heated is, the more efficient the heat pump system becomes. This is because the temperature of the refrigerant exiting the heat rejecting heat exchanger in the heat pump is lower when the liquid to be heated is lower, and this causes the enthalpy entering the heat absorbing heat exchanger to be lower, allowing the refrigerant to absorb more heat and to reject this heat into the liquid to be heated, increasing the efficiency of the heat pump process. This is

especially true for transcritical vapor compression heat pump systems using carbon dioxide as the refrigerant.

[0004] When the heat pump system has satisfied its setpoint conditions, it is typically shut off until the control system determines it is appropriate to turn the system on again. While the system is off in low ambient conditions, it is possible (given enough time) that the liquid outside the storage reservoir can freeze, impacting the performance and possibly damaging the equipment. Prior art methods for preventing this freezing are to circulate the liquid at low flow rate through the system outside the storage tank by using the same pump normally used to circulate the liquid while the system is on.

[0005] In the known method, the cold liquid from outdoors enters the hot section of the storage reservoir. This cools the hot section of the reservoir and may even start mixing the liquid in the reservoir because of the density differences. What results is a reservoir of warm liquid, rather than a reservoir with a hot section and a cold section. The liquid that comes out of the reservoir for use is therefore warm instead of hot. Also, the liquid that leaves the tank to go to the heat pump is warm instead of cold, which reduces the efficiency of the heat pump.

SUMMARY OF THE INVENTION

[0006] In the heat pump system of the present invention, the pump is used to circulate liquid through the system to prevent freezing when the heat pump is off, but the liquid is circulated in the reverse direction. Because the liquid used to prevent freezing comes from the hot section of the storage reservoir, the flow rate can be reduced while achieving the same amount of freeze protection. Also, as the hot liquid is circulated

through the system at the low flow rate, it will become cold through heat transfer with the system as it prevents freezing and will be delivered to the cold section of the storage reservoir at a low temperature. This keeps the cold section of the liquid storage reservoir cold. As indicated above, the colder the temperature of the liquid supplied to the heat pump during operation, the more efficient the heat pump system will be. The present invention also prevents the cold liquid from lowering the temperature of the hot section of the storage reservoir during the freeze protection mode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Other advantages of the present invention can be understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0008] Figure 1 schematically illustrates the heat pump system of the present invention when the heat pump is on.

[0009] Figure 2 shows the system of Figure 1 when the heat pump is off and in freeze protection mode.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Figure 1 illustrates a heat pump liquid heating system 20 according to one embodiment of the invention. The system 20 includes a liquid storage reservoir 22 containing a hot section 24 above a cold section 26. The hot section 24 supplies hot water for use by users and the cold section 26 receives unheated water from a water supply. In the particular embodiment shown, the liquid is water and the system 20

provides hot water for use in a residence or business, but the invention could be applied to other liquids and other applications.

[0011] The liquid storage reservoir 22 of the type shown would typically be installed indoors, while a heat pump 30 is installed outdoors. The heat pump 30 includes a heat rejecting heat exchanger 32, expansion valve 34, heat absorbing heat exchanger 36 and compressor 38.

[0012] A pump 40 pumps fluid from the liquid storage reservoir 22 to and from the heat pump 30. The pump 40 and heat pump 30 are switched based upon temperature sensors 42 and 44. Temperature sensor 42 measures the temperature of the liquid in the liquid storage reservoir 22. Temperature sensor 44 measures the temperature of the liquid entering the pump 40. Lines 46 connect the liquid storage reservoir 22, pump 40 and heat pump 30.

[0013] In operation, when the temperature sensor 42 measures a temperature below a first set point in the liquid storage reservoir 22, the pump 40 and heat pump 30 are switched on. The pump 40 pumps the cold water from the cold section 26 of the liquid storage reservoir 22 to the heat pump 30 where it is heated by the heat rejecting heat exchanger 32 and returned to the hot section 24 of the liquid storage reservoir 22. When the temperature of the liquid entering the pump 40 from the cold section 26 exceeds a second set point, the heat pump 30 is switched off until the temperature measured by temperature sensor 42 drops below the first set point again.

[0014] To prevent freezing while the heat pump 30 is off, the pump 40 is switched to pump in the reverse direction at a low flow rate, as shown in Figure 2. While the heat pump 30 is off, the pump 40 pumps water from the hot section 24 of the liquid

storage reservoir 22 to the heat rejecting heat exchanger 32 of the heat pump 30, and from the heat exchanger 32 to the cold section 26 of the liquid storage reservoir 22. If the ambient outdoor temperature is below freezing, the hot liquid leaving the hot section 24 will more easily prevent freezing of the lines 46, pump and heat pump 30, thus permitting a lower flow rate than in prior art systems. The cold water returning from outdoors will be returned to the cold section 26 of the liquid storage reservoir 22, thus preventing mixing of the hot and cold sections 24, 26 in the liquid storage reservoir 22.

[0015] The pump 40 may switch to the freeze-prevention reverse direction mode whenever the heat pump 30 is off. Alternatively, the pump 40 may switch to the freeze-prevention mode only when the temperature sensor 44 measures liquid temperature below a third set point (e.g. slightly above freezing). As another alternative, a third temperature sensor (not shown) could be provided to measure only the outdoor temperature, so that the pump 40 switches to the freeze-prevention mode based upon the outdoor temperature, or some combination of the outdoor temperature and temperature measured by sensor 44.

[0016] While in freeze-prevention mode, the liquid in the liquid storage reservoir 22 is kept hot, so that hot liquid is available to users at all times. Later, while still in freeze-prevention mode, when the temperature measured by the temperature sensor 42 in the liquid storage reservoir 22 again drops below the first set point, the heat pump 30 will switch on and the pump 40 will again switch direction and take the cold water from the cold section 26 to be heated by the heat pump 30. The fact that the cold section 26 is kept cold increases the efficiency of the heat pump 30, which is more efficient at heating cold water than warm water.

[0017] In accordance with the provisions of the patent statutes and jurisprudence, exemplary configurations described above are considered to represent a preferred embodiment of the invention. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope. For example, separate pumps could be provided for pumping the fluid in each of the opposite directions.